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Determination of Vegetation Change Using Thematic Mapper Imagery in Afşin-Elbistan Lignite Basin; SE Turkey

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Abstract

In this study Landsat Thematic Mapper (TM) and Landsat Enhanced Thematic Mapper plus (ETM+) data for the years 1989-2000-2010 was used to detect vegetational change in Afsin Elbistan lignite basin. Study based on application of Normalized Difference Vegetation Index (NDVI). The change of vegetation cover is determined by comparing different date NDVI images using differencing method. Differencing NDVI images helped to quickly identify areas where vegetation is increased or decreased. The results suggest that NDVI have revealed significant changes in green vegetation in the study area. Remote sensing techniques and multi temporal satellite data reliably used to monitoring changes of vegetation cover in open pit mine areas.

Keywords: NDVI, image differencing, Afşin-Elbistan Lignit;

1. Introduction

One of the major impacts of surface mining is local environmental problems like soil erosion, pollution of rivers and streams, degradation of forested and agricultural lands. In order to turn mining areas to pre-mining condition reclamation process is performed. A successful reclamation program must include a monitoring component to identify areas of successful reclamation, as well as areas where management problems exist or where reclamation practices are failing [1]. The increased availability of Landsat data gives the opportunities for the implementation of remote sensing techniques to monitoring environmental changes around open pit mine areas. A review of the literature indicates that satellite and aerial remote sensing data have been widely and effectively used monitoring environmental effects of surface mining activities and determination of open pit mining areas.

Previous studies around AEL basin are generally focused on determination of lignite reserve, Stratigraphy and basement rocks of basin e.g. petrographical investigation of lignite samples, slop failure. There is no study performed in the area to monitor vegetation change due to open pit mining activity and reclamation process. This paper discusses the vegetation change in Afsin Elbistan open pit coal mine area. Differencing NDVI images from different dates helped to quickly identify areas where vegetation had increased or decreased over the time.

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2. Materials and Methods

2.1. Study Area

Afsin-Elbistan lignite basin is the largest lignite reserve (3,357 × 106 ton) of Turkey, is located at the south-eastern of Turkey (Fig. 1). Lignite basin is divided into three major sectors (Kislakoy (A), Collolar (B), Afsin (C)) and three subsector. Lignite production is carried on Kislakoy sector as an open-pit mine. Major part of the lignite is used in Afsin-Elbistan A and B thermal power plants having supply 7 % energy of Turkey [2].

The reclamation process has been started in Kislakoy open pit mine area since 1987 [3]. From 1987 to 2008 approximately 565.785 threes planted in 605 ha area [4]. The species and percentages of planted trees during reclamation process are given in Table 1.

Table 1. Planted trees during reclamation process

NAME	%	NAME	%
Acacia	26.38	Meyle	0.89
Black pine	23.89	Maple	0.09
Cedar	34.51	Oleaster	0.18
Silver birch	3.45	Mahalep	5.31
Ash tree	2.71	Juniper	0.38
Sofura	2.13	Blue spruce	0.09

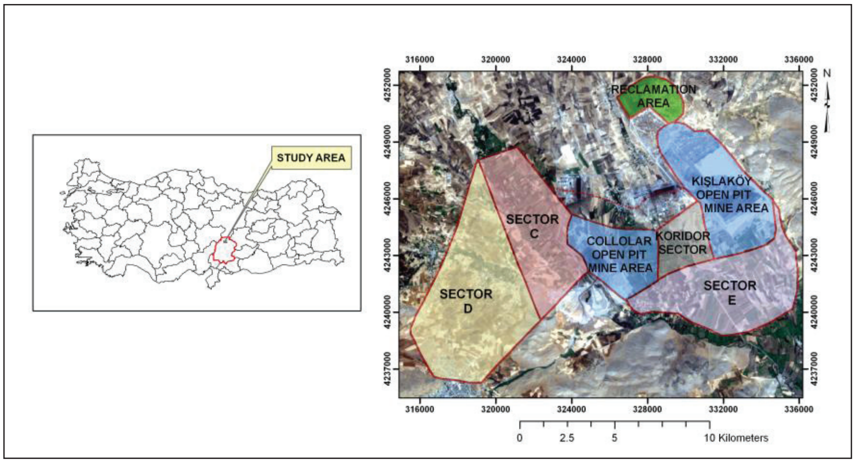

Fig. 1. Afsin–Elbistan lignite basin and sectors modified from [5]

2.2. Data

In the study, Landsat TM and ETM images belonging to years 1989, 2000 and 2010 were used to monitor vegetational change in AEL mine area. These images were downloaded freely from Global Land Cover Facility (GLCF) web page [6] Landsat TM has seven bands with a spatial resolution of 30 meters for Bands 1 to 5 and 7. Spatial resolution for Band 6 (thermal infrared) is 120 meter.

Landsat ETM has eight bands sensitive to different wavelengths. Six of these bands detect visible (1, 2, 3), near infrared “NIR” (4), short wave infrared “SWIR” (5, 7), one thermal and one panchromatic. Spatial resolution is 30 meters for Bands 1 to 7, 15 meter for panchromatic and 60 meter for thermal bands. Characteristics of Landsat image used in the study are given in Table 2.

Table 2. Characteristics of data used in the study

Satellite data	Acquisition date	Path	Row
Landsat TM	1989 June 24	174	033
Landsat ETM	2000 June 24	174	033
Landsat ETM	2010 August 14	174	033

2.3. Normalized Difference Vegetation Index

Vegetation indices have been extensively used to monitor changes related to vegetation. Many vegetation indices have been derived based on numerical combinations of red and near-infrared values of remotely sensed data A ratio of near infrared (NIR) and red bands (TM4 / TM3) is useful in mapping vegetation and vegetation condition. The ratio is high for healthy vegetation, but lower for yellow vegetation and for non vegetated areas. Simple band ratio used for vegetation detection has some deficiencies. First present noise in the image is amplified by image ratio. Another deficiency is generated decimal ratio values changes between 0 and 255 makes some difficulties in the interpretation of the results that requires rescaling. In order to avoid these deficiencies NDVI is used. This is a different technique which demonstrates the best vegetation change detection as judged by laboratory and field results [7] introduced by [8], and now it is a standard method for vegetation analysis. In NDVI corresponding cell values in the two bands are first subtracted, and this difference is then “normalized” by dividing the sum of two brightness values. The formula for NDVI calculation is:

$$NDVI = (Near\text{-}infrared - Red) / (Near\text{-}infrared + Red) \quad (1)$$

NDVI values range from –1 to +1 making interpretation and scaling easy. Positive values represent active vegetation, and near-zero or negative values represent other types of materials.

NDVI was computed for each of the three images belonging to years 1989, 2000 and 2010. The NDVI results 1989, 2000 and 2010 were given in fig.2 (a), (b) and (c). According to generated results of NDVI values maximum changes observed in 2000. NDVI values changes between -0.57 and 0.80. Summary statistics of generated NDVI maps are given in Table 3.

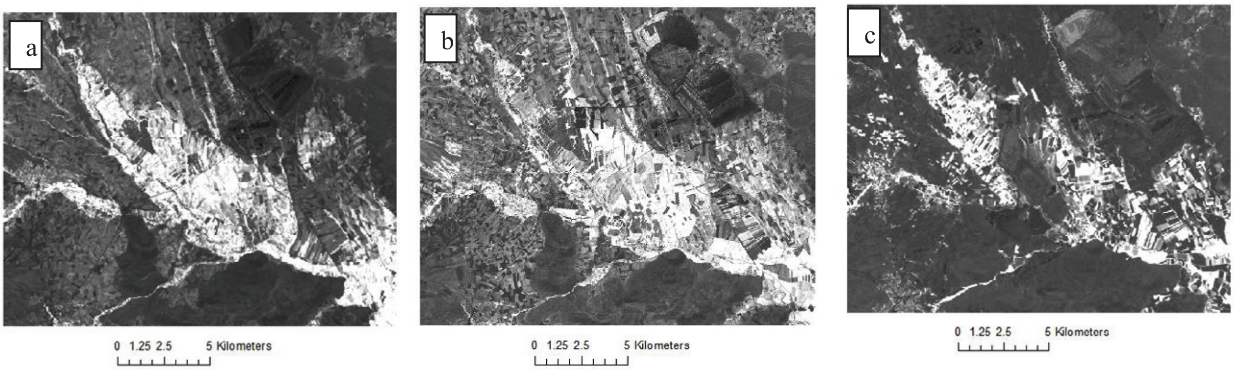

Fig. 2. NDVI images (a) 1989; (b) 2000; (c) 2010

Table 3. Summary statistics of NDVI images

	1989 NDVI	2000 NDVI	2010 NDVI
Minimum	-0.40	-0.57	-0.21
Maximum	0.76	0.80	0.71
Mean	0.08	0.12	0.07
Standard Deviation	0.16	0.20	0.13

2.4. Image Differencing

Selection of the most suitable change detection method starts with the identification of the problem [9]. Comparison of image pairs archived from long term historical records offers the potential to detect and quantify land cover changes occurring in land cover [10].

NDVI differencing is a useful method to detect the changes occurring in open pit mine area. In order to generate NDVI difference image, NDVI scene of 1989 was subtracted from NDVI scene of 2000 and NDVI scene of 2000 from the NDVI scene of 2010 (Fig. 5 (a) and (b)). Result images show both increase and decrease in the NDVI values. In order to see change and no change areas, obtained NDVI difference images are thresholded using mean ± STD. Summary statistics of NDVI difference maps and used threshold values are given in Table 4.

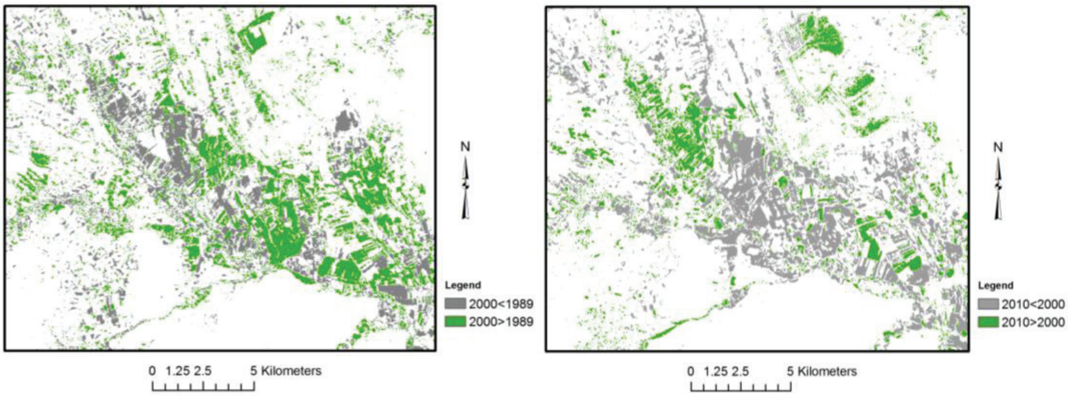

Fig. 5. NDVI difference images (a) 2000-1989; (b) 2010-2000

Table 4. Summary statistics of NDVI difference maps

	NDVI 2010-2000	NDVI 2000-1989
Minimum	-0.814	-0.805
Maximum	0.822	0.820
Mean	-0.054	0.036
Standard Deviation (std)	0.185	0.163
Upper Threshold (mean+std)	0.132	0.199
Lower Threshold (mean-std)	-0.239	-0.127

2.5. Accuracy Assesment

The error matrix is a standard method for assessment of the classification accuracy [11]. In this study, accuracy assessment of binary classification is tested using error matrix generated for two classes. Error matrix includes the correctly classified class both on image and reference data (a), classes that are classified but not present in reference data (b); unclassified classes but present in reference data (c) and unclassified class both on classified and reference data. Correct predictions (a+b); incorrect predictions (b+c); error rate (a+b/ b+c) and accuracy (a+b/a+b+c+d) is easily calculated using error matrix of binary data.

3. Discussion

NDVI easily separated vegetated areas from areas with little or no vegetative cover. Active mine areas indicates low NDVI values; however, high NDVI values are mostly indicated reclaimed and vegetated areas. The results of NDVI have ranged from -0.40 to 0.76, -0.57 to 0.80 and -0.21 to 0.70 in 1989, 2000 and 2010, respectively.

Accuracy assessment is performed for NDVI images belonging to years of 2000 and 2010 due to the availability of the reference data. High resolution Google Earth SPOT image from 29 June 2008 and true color display of VNIR bands of ASTER image from 31 August 2002 are used as reference data. Accuracy assessment is performed at randomly selected 75 point location. The location of selected points both on NDVI final map and reference image data belonging to approximately same year are compared to check whether vegetation on the selected point has present or not. The error matrix is generated to assess accuracy of NDVI maps. According to generated results, accuracy of NDVI images belonging to years 2000 and 2010 are 71% and 68%, respectively (Table 5).

Table 5. Accuracy of NDVI maps

	NDVI 2000	NDVI 2010
Number of Sample Points	75	75
Correct predictions	53	51
Incorrect predictions	21	24
Error Rate	2.52	0.32
Accuracy (%)	71	68

Pixel wise Vegetation cover change in AEL basin is determined using NDVI differencing methods. In this method NDVI images were subtracted from one another, to produce an image of change over a given period of time. The NDVI image differences of 1989-2000 and 2000-2010 demonstrated a noticeable change in the overall NDVI values in twenty-one years. From years 1989 to 2000, 14.44% positive and 7.59 % negative change was observed in the area; however, from years 2000 to 2010 positive changes decreased to 10.34% and negative changes increased to 12.55% results are given in (Table 6). Final image maps showed a transition from barren or sparse vegetation to a denser vegetation cover around the increment of the cultivated areas in Kışlaköy reclaimed area.

Table 6. Positive and Negative Vegetational Change

	NDVI 2010-2000	NDVI 2000-1989
Positive change (%)	10.34	14.44
No change (%)	77.11	77.96
Negative change (%)	12.55	7.59

4. Conclusion

Remote sensing data are useful for the investigation and monitoring vegetational change in open pit mining areas over a long period of time. It gives unbiased information about the changes of areas in a given period of time. This method would be useful to identify areas where vegetation may be stressed, or where reclamation may be failing. NDVI image differencing is successfully used to follow the long-term success of reclamation. Pixel wise Differencing NDVI images from different dates helped to quickly identify changed areas over time.

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